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Original articles

The natural course of osteoarthritis of the hip due to subluxation or acetabular dysplasia

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Summary. In 59 patients, 86 hips with subluxation or hip dysplasia were examined to determine the natural course of the condition and select suitable treatment. Thirty-three percent of the joints (13/39 hips) developed early osteoarthritis from pre-osteoarthritis within an average term of 9.2 years, while the remaining, sixty-six percent (31/47 hips) developed advanced-stage osteoarthritis from early osteoarthritis within an average term of 7.8 years. Patients were classified into advanced and non-advanced groups according to radiographic analysis of the advance of the disease and statistical analysis was performed. In pre-osteoarthritis, centre-edge angle, slope of the acetabular roof, acetabular head index, acetabular depth ratio and Japanese Orthopaedic Association (JOA) hip score were significant predictors, while in early osteoarthritis, a broken Shenton's line, cranial joint space and JOA score were significant. On the basis of multiple parameters, formulas for predicting development in patients with pre-osteoarthritis, those with early osteoarthritis, and all patients together were established, with an accuracy of 87%, 71%, and 68%, respectively.

In European countries, primary osteoarthritis is more common than secondary osteoarthritis [2]. The opposite is true in Japan, where secondary osteoarthritis of the hip, especially due to congenital dislocation or acetabular dysplasia, is more common than primary osteoarthritis.

Knowledge of the natural course of osteoarthritis of the hip with subluxation or hip dysplasia is very important for determining more precise and more appropriate treatment. There have been only a few studies investigating whether joint congruence, radiographic parameters, or daily life activities influence the natural course. Wiberg [13] reported that the centre-edge (CE) angle and a broken Shenton's line were significant factors which appear in the advanced stage of osteoarthritis. However, Cooperman et al. [1] and Ninomiya et al. [8] later reported that there was no radiographic indicator which significantly affected the natural course. Such results can be largely explained by the fact that cases of subluxation were not included in these studies.

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The purpose of this paper is to report on the natural history of osteoarthritis of the hip, and to establish methods for early and accurate prediction of the development of osteoarthritis in patients with subluxation or acetabular dysplasia of the hip.

Material and methods

All patients with either pre-osteoarthritis (pre-OA) or early osteoarthritis (early OA) were examined radiogoraphically and clinically in Nagoya University Hospital and five affiliated hospitals. These patients, with or without a history of congenital dislocation of the hip (CDH) or acetabular dysplasia, were followed for more than 10 years. Patients in whom epiphyseal closure had not yet occurred were excluded; most were over 15 years old. The pre-OA group was made up of those patients in whom no sclerotic change in the acetabulum or the femoral head was visible radiographically. Early OA was defined by absence of joint space narrowing with or without sclerotic change in the acetabulum or the femoral head. Patients with a history of surgical treatment, contralateral hip osteotomy, total hip arthroplasty, or hip dislocated into the gluteal muscles were excluded from the study. Documentation and conventional radiographs were available for all patients.

Pre-OA is defined as the stage before radiographic changes are visible by conventional radiography: early OA is diagnosed when there are sclerotic changes without joint space narrowing. Advanced OA is the stage of joint space narrowing and terminal OA is the stage at which the joint space has disappeared.

A total of 86 hips were evaluated in 59 out of a total of 94 patients including those with advanced and final stages of osteoar-

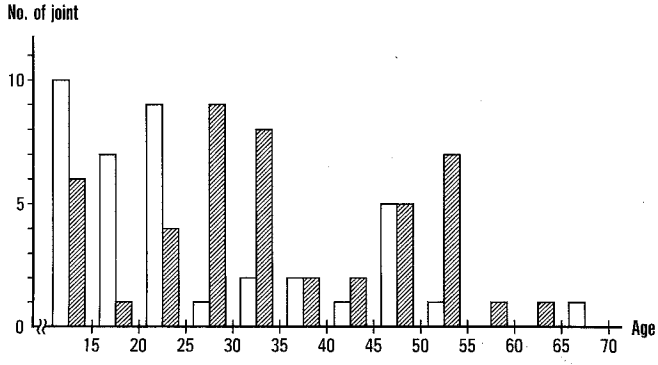

Fig. 1. Age distribution of patients with pre-OA and early OA. Average age at the time of first consultation was 29.9 years. Pre-OA patients were on average 7 years younger than early OA patients. □ Pre OA, ▨ early OA

Table 1. Japanese Orthopaedic Association (JOA) score for osteoarthritis of the hip

Pain (40 points)		Mobility (20 points)				Walking (20 points)	
Pain	Score	Flexion	Score	Abduction	Score	Ability	Score
None	40	>90°	12	>30°	8	Normal	20
Mild	30	60°–89°	9	20°–29°	6	Without cane but with slight limp	15
Moderate	20	30°–59°	6	10°–19°	4	With one cane and with moderate limp	10
Marked	10	10°–29°	3	<9°	2	Only with crutches and marked limp	5
Disabled	0	<10°	0	Contracture	0	Disabled	0

Function in daily activities (20 points)	Able with ease	Able with difficulty	Unable
Sitting on chair	2	1	0
Sitting down on the heels	2	1	0
Bending while sitting	2	1	0
Crouching	2	1	0
Putting socks on and off	2	1	0
Cutting toenails	2	1	0
Standing up	2	1	0
Standing on one leg	2	1	0
Going upstairs	2	1	0
Going downstairs	2	1	0

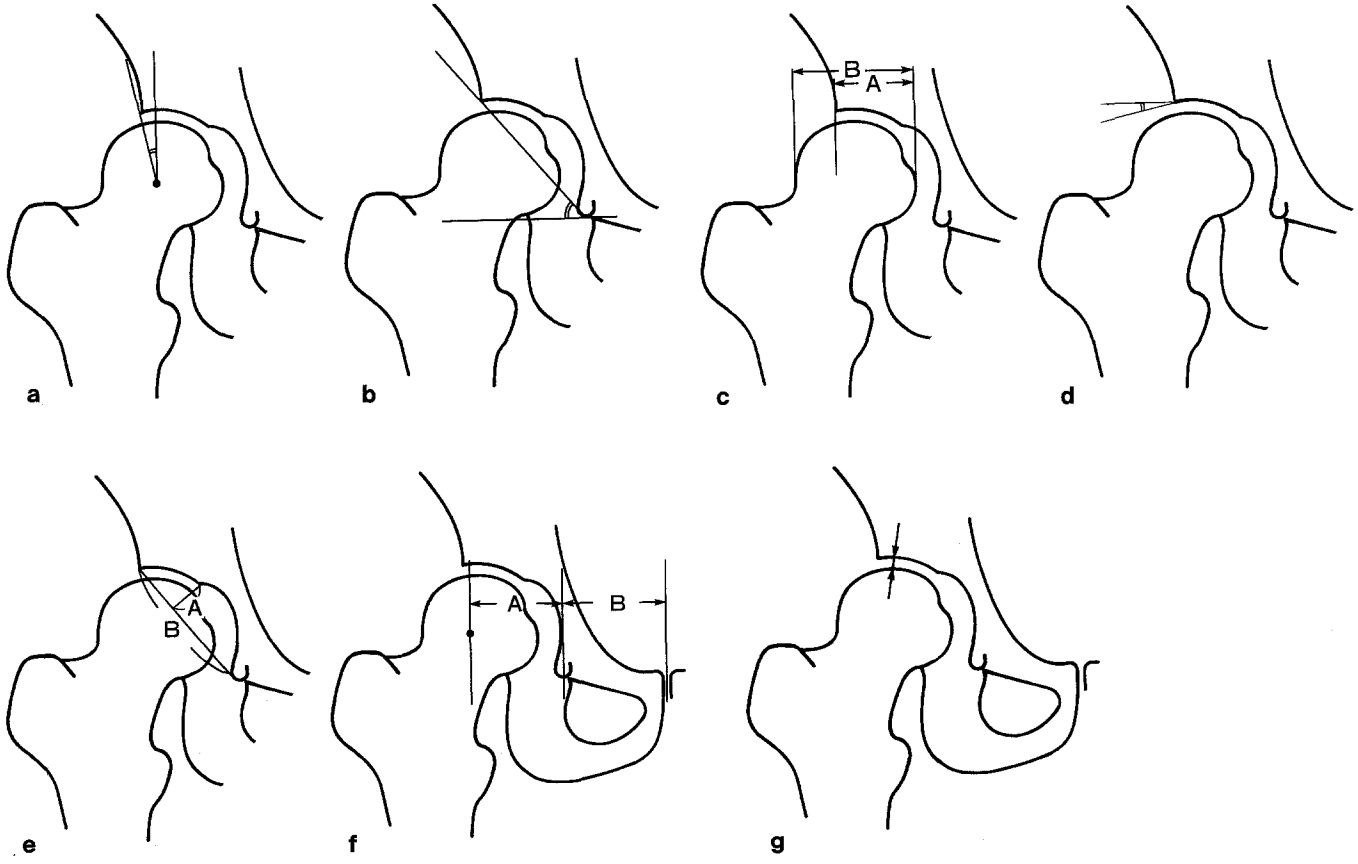

Fig. 2. Radiographic measurements. **a** Centre-edge (CE) angle of Wiberg; **b** acetabular angle; **c** acetabular head index (AHI) = $A/B \times 100$; **d** slope of acetabular roof; **e** acetabular depth ratio (ADR) = $A/B \times 1000$; **f** head lateralization index (HLI) = $A/B \times 100$; **g** cranial joint space, i.e. the weight-bearing joint space

thritis. The average at first consultation was 29.9 years (range 13–61 years), the age distribution being skewed towards patients in their teens and twenties (Fig. 1). There were 54 female patients (79 hip joints evaluated) and 5 male patients (7 joints evaluated). Fifty patients were bilaterally affected; in only 9 was only one hip affected.

Radiological assessment of stage resulted in 39 hips being classified into the pre-OA group and 47 into the early OA group. In the bilateral cases, the combination of stages was as follows: both hips pre-OA, 30 patients; one hip pre- and one hip early OA, 18 patients; one hip pre- and one advanced or final stage, 2 patients; and one hip early and the other advanced or final stage, 8 patients. The average follow-up period was 12.8 years (range 10–25 years).

Clinical assessment used the Japanese Orthopaedic Association (JOA) score (Table 1); in addition, age, sex, history of CDH, body height and weight, affected side, stage of osteoarthritis, onset of pain, leg length discrepancy (spinal-malleolar distance, SMD) and Trendelenburg sign were recorded.

Anteroposterior radiographs were taken at the time of this study to look for the following; bone sclerosis, bone cyst, bony spur, joint incongruence, deformity of femoral head (round, ovoid or other), height of greater and lesser trochanter, and a broken Shenton's line (more than 10 mm was defined as positive). Joint congruence was defined as the absence of femoral head deformity, a femoral head radius not more than that of the acetabulum, or a CE angle greater than 0°. The following radiographic measurements were calculated by a computer-aided digitizer (Fig. 2): CE angle of Wiberg, acetabular angle of Sharp, acetabular head index (AHI) of Heyman and Herndon, slope of acetabular roof, acetabular depth ratio of Cooperman et al. [1], head lateralization index (HLI), and cranial joint space, which indicated the weight-bearing joint space.

Statistical analysis was performed with the Student's t test or χ^2 test. On the basis of statistically significant parameters, formulas were generated for predicting advancement of osteoarthritis of the hip after more than 10 years from the first hospital consultation.

Results

Thirteen of the 39 hips in the pre-OA group developed early OA, and further development to advanced or final stage was observed in four hips with an average of 12.8 years' follow-up. The average period of advancement to the next stage was 9.2 years. Thirty-one of the 47 hips in the early OA group developed advanced stage or final stage OA with an average follow-up of 12.8 years. Advancement to the final stage was observed in six hips. The average period of advancement to the next stage was 7.8 years.

Table 2. Variables in pre-osteoarthritis patient group in relation to outcome (mean ± SD)

	Outcome group		
	Advanced	Non-advanced	
CE angle	3.7 ± 10.0	12.9 ± 9.1	**
Acetabular angle	49.1 ± 4.5	46.9 ± 4.9	NS
AHI	57.2 ± 10.8	69.1 ± 9.2	**
Slope of acetabular roof	−10.2 ± 10.3	−1.8 ± 7.1	**
Acetabular depth ratio	174.1 ± 32.8	218.6 ± 37.5	**
HLI	65.2 ± 12.9	59.5 ± 10.5	NS
Cranial joint space	5.3 ± 1.0	5.0 ± 1.0	NS
JOA score (total)	94.8 ± 5.7	98.1 ± 3.7	*
JOA score (pain)	37.7 ± 4.4	38.5 ± 3.7	NS
Body weight (kg)	48.4 ± 3.2	48.8 ± 9.1	NS

CE, Centre-edge; AHI, acetabular head index; HLI, head lateralization index; JOA, Japanese Ortopaedic Association
*$P < 0.05$, **$P < 0.01$; NS, not significant

Table 3. Variables in early osteoarthritis patient group in relation to outcome (mean ± SD)

	Outcome group		
	Advanced	Non-advanced	
CE angle	1.1 ± 15.0	−2.3 ± 13.6	NS
Acetabular angle	49.2 ± 6.1	49.9 ± 4.9	NS
AHI	56.8 ± 14.6	53.1 ± 13.3	NS
Slope of acetabular roof	−11.5 ± 10.9	−12.2 ± 12.1	NS
Acetabular depth ratio	162.7 ± 51.7	160.2 ± 48.0	NS
HLI	70.5 ± 13.0	72.1 ± 11.0	NS
Cranial joint space	5.0 ± 1.4	6.0 ± 1.8	*
JOA score (total)	88.5 ± 9.4	92.2 ± 6.5	*
JOA score (pain)	33.3 ± 5.5	35.0 ± 5.2	NS
Body weight (kg)	52.4 ± 8.3	51.9 ± 4.9	NS

Abbreviations: see Table 2
*$P < 0.05$, **$P < 0.01$; NS, not significant

Table 4. Variables in pre- and early osteoarthritis groups together in relation to outcome (mean ± SD)

	Outcome group		
	Advanced	Non-advanced	
CE angle	2.3 ± 13.8	5.1 ± 14.8	NS
Acetabular angle	48.8 ± 5.7	48.1 ± 6.0	NS
AHI	57.6 ± 13.8	61.8 ± 14.2	NS
Slope of acetabular roof	−10.8 ± 10.6	−8.5 ± 12.1	NS
Acetabular depth ratio	160.3 ± 49.0	183.2 ± 56.5	*
HLI	69.6 ± 12.1	70.5 ± 16.4	NS
Cranial joint space	4.6 ± 1.6	4.3 ± 2.1	NS
JOA score (total)	91.5 ± 10.6	95.1 ± 11.0	NS
JOA score (pain)	34.7 ± 5.5	37.3 ± 4.5	*
Body weight (kg)	50.1 ± 6.6	49.9 ± 8.0	NS

Abbreviations: see Table 2
*$P < 0.05$, **$P < 0.01$; NS, not significant

Patients were divided into two outcome groups, advanced and non-advanced OA, according to the radiographic analysis of development after 10 years of follow-up.

In the pre-OA patients, statistical analysis of the radiographic assessment in relation to outcome group showed CE angle, AHI, the slope of the acetabular roof, the acetabular depth ratio, and the JOA score to be significant predictors (Table 2). In the early OA patients, only cranial joint space ($P < 0.05$), total JOA score and a broken Shenton's line ($P < 0.01$) were statistically significant (Table 3). In all patients (both pre- and early OA groups taken together), joint incongruence ($P < 0.05$), femoral head deformity ($P < 0.01$), abnormal position of the lesser trochanter ($P < 0.05$) and a broken Shenton's line ($P < 0.01$) were statistically significant (Table 4).

Age, sex, history of CDH, body weight and height, contralateral hip conditions, onset of pain, SMD and the

Table 5. Formulas for predicting the progress of osteoarthritis of the hip

Z_1[a] = −5.94 + 0.019 × JOA + 0.0045 × SAR −0.072 × CE + 0.055 × AHI + 0.0063 × ADR −0.071 × S +0.32 × type I (or −0.53 × type II)

Z_2[a] = −5.06 + 0.050 × JOA + 0.41 × J −0.61 × T −0.79 × type I (or −1.48 × type II)

Z_3[a] = −2.12 −0.053 × CE + 0.036 × AHI −0.0068 × ADR −0.18 × Pain −0.28 × AS −0.17 × JI + 0.18 × T −0.24 × S −0.11 × type I (or −0.76 × type II)

[a] Z_1, Z_2 and Z_3: Formulas for pre-OA, early OA, and pre- and early OA together, respectively. If Z is negative, OA will be expected to advance
JOA, JOA score: SAR, slope of acetabular roof; CE, centre-edge angle; AHI, acetabular head index; ADR, acetabular depth ratio; S, broken Shenton's line (more than 10 mm higher than normal Shenton's line = 1; 0–9 mm = 0); J, cranial joint space; T, position of lesser trochanter (more than 10 mm higher than in contralateral hip = 1; 0–9 mm = 0); pain, JOA pain score; AS, acetabular sclerotic change; JI, joint incongruence; type I, round; type II, ovoid shape of the femoral head

Trendelenburg sign were not statistically significant predictors in this study.

Using the χ^2 test in pre-OA patients, an AHI of less than 60 ($P < 0.01$), an acetabular depth ratio of less than 200 ($P < 0.05$), and an acetabular roof slope of less than −5° ($P < 0.01$) were all significantly associated with development to early OA. There was no significant association for the CE angle.

Using limited factor analysis, prediction formulas were established for pre-OA, early OA and both groups together (Table 5). In pre-OA patients, the correlation coefficient of this formula was 0.55 and the accuracy of prediction was 87.2%. In early OA patients, the correlation coefficient was 0.25 and the prediction accuracy was 71.1%. In all patients together, the correlation coefficient was 0.28 with a prediction accuracy of 67.9%.

Discussion

In Japan, osteoarthritis is in more than 90% of cases secondary to residual subluxation after treatment for CDH or acetabular dysplasia; the incidence of primary osteoarthritis is extremely low compared to that in western countries [8, 10]. The introduction of the idea of early treatment for CDH led to a dramatic decrease in the incidence of CDH [11, 12].

Most patients would never complain of hip pain or limping at a younger age, even if treated in the neonatal or infantile period. For this reason it is very difficult to obtain a clear picture of the natural course of osteoarthritis of the hip [5]. Furthermore, patient selection is most important, but is difficult to maintain in an accurate epidemiological study: loss of follow-up and drop-out due to surgical treatment could strongly influence the results of such retrospective studies (Fig. 3). In our University Hospital, more than 2000 patients with osteoarthritis of the hip were registered. However, only 150 patients could be followed for more than 10 years without any surgical

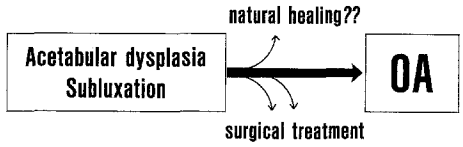

Fig. 3. What is the natural course of osteoarthritis of the hip? Patients selection, to get the natural history of the osteoarthritis of the hip is extremely difficult because of the drop-out surgically treated or naturally healed patients

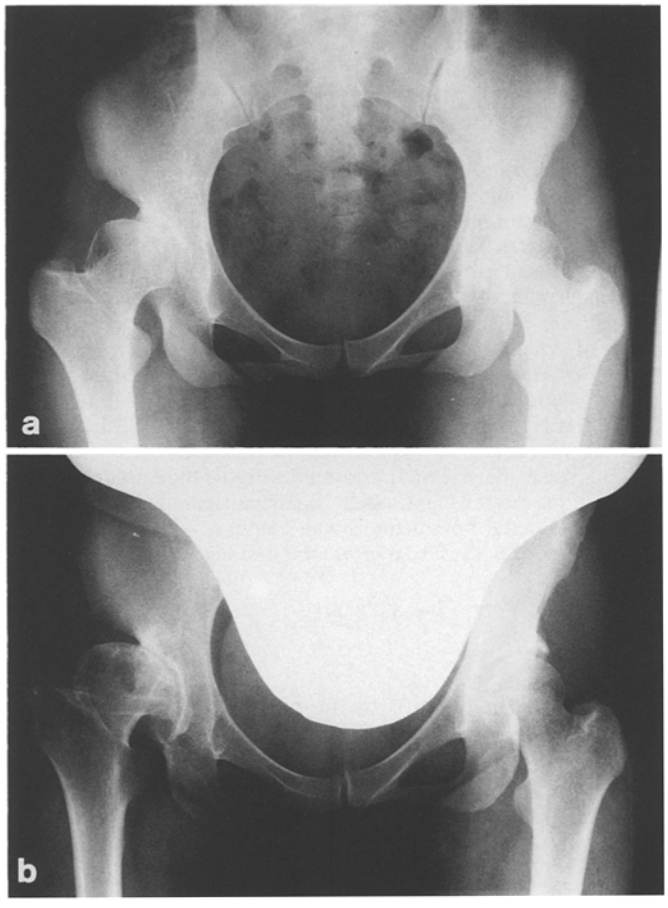

Fig. 4a, b. Radiographs of a 23-year-old woman with bilateral osteoarthritis of the hip. She has a past history of treatment for CDH. The right hip showed subluxation and an irregularly shaped femoral head; the CE angle was −20° and AHI was 33. Seventeen years after her first consultation, the right hip, as expected, had developed advanced OA, but the left hip showed natural healing of the acetabulum and the CE angle was restored from 17° to 22°

treatment to at least one hip: only 8% of the patients. With, in addition, the rare cases of natural healing of acetabular dysplasia, discussion of the natural course of osteoarthritis of the hip becomes very difficult (Fig. 4).

Scolan [9] reported that hip dysplasia with subluxation developed to osteoarthritis. She divided hip joint deformities into five groups and was convinced that hip dysplasia was an important factor in the development of osteoarthritis of the hip. Wiberg [13] reported that a small CE angle and a broken Shenton's line preceded the development of osteoarthritis in 7 out of 19 long-term follow-up

patients. Moreover, osteoarthritis had developed at a rate correlating with the CE angle.

However, Cooperman et al. [1] denied the development of osteoarthritis of the hip in their study. Their findings showed that without subluxation of the hip, even if the CE angle was small there would no development of osteoarthritis. Ninomiya et al. [8] reported that age was the only significant factor in the development of osteoarthritis, and that no radiographic parameters were meaningful for prediction.

The findings in our study suggest that surgical treatment should be performed to prevent the advance of osteoarthritis. Firstly, patients with CE angle of less than 0° without subluxation, or a broken Shenton's line of more than 10 mm, or a CE angle of less than 10° with subluxation, should be operated on to prevent osteoarthritis. Secondly, if the AHI is less than 60, or if the acetabular roof angle is less than −5°, or the acetabular depth ratio is less than 200, surgical treatment should also be performed.

Good results have been reported for many surgical procedures, including femoral varus and valgus osteotomy, and periacetabular osteotomy. Many authors have said that precise osteotomy for biomechanical improvement should be selected to prevent the advancement of osteoarthritis.

In bilateral cases, one would expect contralateral hip conditions to affect the normal course, but there was no significant difference in this study. Out of 25 bilaterally affected patients with contralateral varus osteotomy excluded from this study, 4 had advanced from pre-OA to early OA 10 years after the first consultation.

Using the prediction formula for pre-OA, an advance of osteoarthritis from this stage of disease can be predicted to a considerable extent. However, the advance from early OA is slightly more difficult to predict. It is considered that in the younger pre-OA patients biomechanical factors predominate over biochemical factors, while, by contrast, in the early OA patients biochemical factors such as proteoglycan or collagen become increasingly predominant, especially in older patients [3, 4]. This finding corresponds well with the report of Ninomiya et al. [7] showing age to be the only factor affecting the advance of osteoarthritis of the hip.

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